2.—CONTRIBUTIONS TO THE MINERALOGY OF WESTERN AUSTRALIA.

Series V.

(With one Figure.)

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CONTENTS.

(1) ANHYDRITE, KALGOORLIE, CEN. DIV.

We owe this, the first discovery of anhydrite in Australia, to the keenness of Mr. W. R. Feldtmann as a field mineralogist. During 1929 he noticed in some small quartz veins at the 1,100ft. (335 metres) level of the Perseverance G.M., masses of a translucent mauve-coloured mineral not unlike fluorite. Laboratory examination, however, showed it to be anhydrite, "violet" coloured types of which are said to be rare.* The rock in which the vein occurs is a carbonated and chloritised greenstone of Archæan age.

The mineral is in coarsely crystalline masses, single cleavages being traceable for distances of 1 to 3 cm. The characteristic three rectangular cleavages are strongly marked. Individual cleavage blocks are translucent in thicknesses of 3 to 10 mm., whilst thin flakes are perfectly transparent. Multiple twinning is noted in many of the pieces of the coarse powder when viewed under the microscope, there being often as many as five successive plates in a width of 0·1 mm. The traces of these plates make angles of approximately 45° with the cleavages, indicating that the twinning is on the already recorded plane (101), the calculated angles for which are 48° 13′. and 41° 47′. This twinning can be detected by the naked eye as a series of fine striations on some of the cleavage blocks.

The colour of the mineral is mostly pale mauve (63′ f) to a little darker than light mauve (63′d), but in some specimens the colour diminishes in parts to practically colourless. The powder under the microscope is perfectly transparent and colourless. It is usually bounded by the perfect rectangular cleavages, and gives a straight extinction in all directions, with very high birefringence.

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*Winchell: Elem. Opt. Min. II., 100.

A mauve-coloured cleavage fragment was selected for analysis with the following results :—

	%	mols.
CaO	40·47	722
SrO	·71	7
BaO	·05	0·3
SO_3	58·94	736
H_2O	·40	22
	100·57	
G	2·97	

The small amount of water indicates incipient alteration to gypsum along the cleavages.

It was found that when ground to an impalpable powder the mineral dissolved rather readily in warm 5N. HCl or HNO_3, but that slightly coarser powder, such as would pass a 90-mesh sieve (max. diam. 0·18 mm.), took many hours to dissolve in nearly boiling acids of the same strength.

(2.) CELESTITE, KALGOORLIE, CEN. DIV.

In the same level of the Perseverance Mine which yielded specimens of strontium-bearing anhydrite, Mr. Feldtmann observed granular masses of a pink colour in a small quartz vein. These on examination, have proved to be an intimate mixture of calcite (about 30 per cent.), quartz (about 10 per cent.), and celestite (about 60 per cent.).

The celestite was separated from its associates by first treating with cold, very dilute, hydrochloric acid, and, after drying the residue, floating off the quartz with methylene iodide. The residue under the microscope was transparent, with a mean refractive index of 1·630, and a moderately low birefringence. By floating in silver thallium nitrate its specific gravity was proved to be 4·08. Chemically it was found to be slowly attacked by hot strong HCl, the solution on diluting giving a precipitate with barium chloride. By fusing with $KNaCO_3$ a carbonate was obtained easily soluble in HCl, the solution giving strong reactions for strontium (confirmed by spectroscope) and weak for barium. Lead was absent.

The optical and chemical properties leave no doubt that the mineral is celestite (strontium sulphate), a mineral not previously known in the State.

(3.) AXINITE, TALBOT BAY, KIM. DIV.

In 1929 when E. C. Francis was exploring the west coast of the Kimberley Division, he found a brownish mineral to be abundant at a point on the shore of Talbot Bay, a deep inlet about 12 miles S.E. of Yampi Sound. This mineral has been found to be axinite, one only previously known in the State in a few small specimens collected by J. A. Thomson at Kalgoorlie.

The mineral occurs in a narrow, much veined, band of rock, characterised by seams of quartz, calcite, and epidote, with occasional schorl, and said to be found in greenstone schist at its junction with gneiss. It exists in wedge-shaped crystals and crystalline masses embedded in vein quartz or calcite, or penetrating both ways from a junction of the two. Single crystals have been observed up to 2 cm. in length, and coarsely crystalline masses up to 250 grammes in weight. It is almost impossible to remove the crystals from their matrix without fracturing them greatly. One crystal which was extracted whole was a combination of *M* (1–10), *m* (110), *b* (010), (2–30)?, *r* (1–11), *s* (201), and *y* (021).

The crystals vary greatly in translucency, some being opaque in thicknesses over 0·5 mm., others being translucent up to 4 mm. The colour too, is variable, ranging from Ridgway 69^4, dark vinaceous grey, to 1^4, purple drab, and nearly to 1^3i, deep livid brown. The fine powder under the microscope is transparent and practically colourless, with medium birefringence.

Before the blowpipe the mineral fuses easily with intumescence, and with CaF_2 and $K_2S_2O_7$ in a relatively cool flame gives the green colour characteristic of boron compounds.

An analysis was made of some of the more transparent brown mineral, carefully separated with methylene iodide. For comparison are given recent analyses of the mineral from Prali (Italy), and Bourg d'Oisans (France) :—

	Prali.	B. d'Oisans.	Talbot Bay.		
	%	%	%	mols.	
SiO_2	41·26	42·78	42·14	702	
Al_2O_3	18·74	17·67	17·67	173	184
Fe_2O_3	2·02	·99	1·74	11	
FeO	6·11	6·02	6·81	95	191
MnO	4·43	2·99	3·09	44	
MgO	1·75	2·41	2·06	52	
CaO	19·52	20·16	19·96	356	
B_2O_3	4·70	6·12	5·56	80	
H_2O	1·71	1·40	1·56	86	
Total	100·24	100·54	100·59		
G	3·31	3·29	3·25		

Dividing the molecules throughout by 88 we obtain the formula—

$$H_2O \cdot 2FeO \cdot 4CaO \cdot 2Al_2O_3 \cdot B_2O_3 \cdot 8SiO_2$$

which is the same as $HFeCa_2Al_2B(SiO_4)_4$.

This is the formula for axinite accepted by N. H. and A. N. Winchell.

(4.) CHLORITOID, KALGOORLIE, CEN. DIV.

In 1915 the writer showed by a detailed comparison of chemical and physical properties that the many minerals described as belonging to the Chloritoid Subgroup could be reduced to one species, chloritoid, and two varieties, viz., ottrelite (manganiferous chloritoid), and sismondine (magnesian chloritoid).* The general formula for the species is $H_2(Fe, Mn, Mg)Al_2SiO_7$. The apparent excess of silica noted in some analyses of ottrelite, etc., is simply due to minute inclusions of quartz, as can be proved by microscopic examination of the minerals and decomposition of the analytical material by concentrated sulphuric acid, followed by Lunge's alkali solution. Phyllite, masonite, newportite, struverite (Brezina 1876), venasquite and salmite are unnecessary synonyms for normal chloritoid or one of its varieties.

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*Geol. Surv. W. Aust. Bull. 64, pp. 64–78. N. H. and A. N. Winchell, Elem. Opt. Mineralogy II., p. 385.

In 1912 the writer described a rock on the Lake View Townsite, Kalgoorlie, which carried many well defined discs of a mineral referred to as ottrelite.* The mineral itself had not been separated and analysed, but, the analysis of the rock as a whole showing a relatively high proportion of manganese, it was assumed that the chloritoid was also rich in manganese. The mineral has now been separated and analysed, with the result that it proves to be a normal chloritoid with occluded quartz granules.

The rock mass in which chloritoid occurs at the Lake View Townsite appears to occupy quite a small area of the Archæan greenstone complex. What it lacks in size, however, it makes up in variations of type. In the writer's collection are no less than a dozen rock specimens from this area, each showing some individual form of structure or mineral composition, but resembling one another in being freely sprinkled with small discs of chloritoid, usually about one millimetre in diameter, and one quarter that in thickness. Some of these rocks are quite massive, others coarsely brecciated, others slightly or highly foliated. All are variants of the intrusive quartz dolerite, as shown by typical relict structures to be seen in thin slices, such as large skeletal ilmenites, or optically parallel archipelagoes of primary quartz. They range from a massive green chlorite rock with less than 10% of carbonates (See Analysis J), through chlorite schist and grey calc schist with 20% of carbonates (See Analysis A), to a pale yellow pyritous mica schist with a smaller proportion of carbonates.

The proportion of chloritoid in the rock varies from about 5 to 15 per cent. of the whole. In some of the rocks it is evenly scattered throughout the whole, but in the brecciated ones it is often more plentiful in the fillings between the broken fragments, and in the schists is often much more plentiful in some bands than in others.

The composition of two of these rocks was as follows :—

	Chloritoid Rocks Kalgoorlie.	
Specimen.	J.	A.
SiO_2	44·93	50·94
Al_2O_3	14·66	12·04
Fe_2O_3	2·68	2·74
FeO	20·12	9·44
MnO	·38	1·06
MgO	4·63	3·04
CaO	2·17	5·47
Na_2O	·02	1·28
K_2O	·16	·66
H_2O+	6·16	2·81
H_2O-	·11	·16
TiO_2	·90	1·09
CO_2	3·34	8·24
P_2O_5	·09	·45
FeS_2	*nil*	·77
Cr_2O_3	?	*nil*
V_2O_3	?	·09
ZrO_2	?	trace
BaO	?	·02
Total	100·35	100·30
G	2·95	2·88

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* Geol. Surv. W. Aust. Bull. 42, pp. 142–3.

Approximate mineral composition :—

Chlorite	48·4	14·2
Quartz	31·8	32·9
Chloritoid	8·6	14·7
Ankerite	7·8	18·6
Ilmenite	1·7	...
Rutile	...	1·1
Muscovite	1·3	5·6
Albite	·2	11·0
Apatite	·2	1·1
Pyrite	...	·8
Magnetite	trace	trace
Tourmaline	...	trace
	100·0	100·0

" J."—A massive, greyish-green chlorite rock.

" A."—A thinly foliated, fine grained, yellowish-grey to greenish-grey rock.

Specimen " E," a completely unweathered, light grey, calc-schist with much visible chloritoid, was crushed and concentrated with methylene iodide, and freed from traces of pyrite by levigation in water. The final product was examined under the microscope and found to be chloritoid free from adherent matter, but embracing some minute inclusions of quartz and rutile. By repeated fuming with sulphuric acid and treatment of the residue with Lunge's solution, it was possible to determine the silica present as free quartz separately. The analytical results obtained were :—

	Kalgoorlie.			Yampi.	
	Concentrate	Recalculated.			
	per cent.	per cent.	mols.	per cent.	mols.
TiO_2 (Rutile)	1·46	...		...	
SiO_2 (Quartz)	7·35	...		...	
SiO_2 (Combined)	21·68	23·74	395	24·31	403
Al_2O_3	35·62	39·01	401	39·18	405
Fe_2O_3	2·78	3·04		3·56	
FeO	21·89	23·98	399	22·64	403
MnO	·45	·49		1·51	
MgO	1·47	1·61		2·70	
CaO	·93	1·02		trace	
H_2O	7·05	7·72	428	6·65	369
	100·68	100·61		100·55	
G	3·46	3·54		3·55	

The composition of the Yampi (Kimberley Division) chloritoid, analysed some years ago is tabulated for comparison. The figures show that when allowance is made for embedded quartz and rutile, detected microscopically and separated chemically, the ratio $SiO_2 : MO : M_2O_3 : H_2O$ proves to be the normal one for chloritoid, viz., 1 : 1 : 1 : 1.

Microscopic examination of slides of eight different types of chloritoid rock from the Lake View Townsite yields the following data. The mineral is usually rather evenly distributed in single crystals through the rock, but in some cases is more thickly grouped in bunches or narrow lenses. Rarely several crystals are connected together in a fan-like arrangement. Individual crystals are disc-like, about 0·5 to 1·5 mm. in diameter and one-quarter to one-third their diameter in thickness. When cut vertically they are seen to be sharply bounded by basal planes but to have ragged boundaries in the prism zone. The latter feature is very evident also in basal sections, only rare traces of a hexagonal outline being noted. Every crystal shows multiple twinning on the basal plane, the individual layers usually extending only part way across the crystal. A similar feature was noted in the Yampi chloritoid and figured on page 75 of Geological Survey Bulletin 64.* Indications of basal and prismatic cleavages are observable. Most crystals are crowded with minute granular inclusions, of which quartz and rutile form by far the greater proportion. By shading off most of the transmitted light it is seen, in practically every instance, that the inclusions are far more plentiful towards the centre basal plane of each crystal, the boundary of the denser mass being concave towards top and bottom of the crystal.†

The Kalgoorlie mineral is strongly pleochroic, that in some rocks being more strongly coloured than in others. Typical schemes observed were :—

	(1.)	(2.)
X.	Chromium green	Rainette green
Y.	Cadet blue	Orient blue
Z.	Light dull green-yellow	Light chalcedony yellow

The dispersion is too strong to observe an extinction angle in white light. Even in sodium light readings were unsatisfactory owing to the abundance of inclusions and polysynthetic twinning. Most readings of the angle Xc were about 4 to 6 deg., but readings up to 11 deg. were obtained.

(5.) GAHNITE, GILLINGARRA, S.W. DIV., AND WODGINA, N.W. DIV.

Gillingarra.—On the slope of a hill about one mile N. of the Government Well at Gillingarra, a number of detrital specimens of gahnite have been found. The rock exposed in the immediate vicinity is an almost vertical mica schist, traversed by occasional epidiorite dykes and many small quartz veins. A few hundred yards to the East the junction of the schists with a gneissic granite can be observed. Both rocks are thought to be of Precambrian age.

The gahnite has been found as scattered grains, from less than one to several millimetres in diameter, freely distributed through loose boulders of reddish weathered mica schist, one specimen yielding 30 per cent. of its weight of the spinel when crushed and concentrated. This concentrate was used for analysis. A section of the rock shows it to be a muscovite schist with subordinate chlorite (often heavily ironstained), biotite, and quartz, and innumerable spheroidal and ovoid grains of transparent green isotropic gahnite. These grains vary in size from 0·1 to 5·0 mm. in diameter and average 1 to 2 mm. Most of them are devoid of crystal faces, but occasionally perfect octahedra have been observed on the fractured faces of the rock, and in the concentrates from it.

Other detrital specimens consist largely of a mixture of gahnite, vein quartz, and ferruginous laterite. A few loose detrital pebbles of practically pure gahnite have been seen. These are mostly only 1 or 2 cm. in diameter, but one weighs 250 grammes and has a density of 4·06, indicating a content of about 80 per cent. of gahnite. Such masses are invariably composed of a number of crystal individuals.

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*Compare also Rosenbusch-Iddings Micro. Physiog. of Rock-making Minerals, Plate XXI. Fig. 2.

† Idem Plate XXI., Fig. 3.

No specimen has yet been found in situ in either schist or quartz, nor are any other zinc minerals known in the vicinity. In Maryland, U.S.A., gahnite occurs in copper-bearing veins in mica schist, in Sweden in similar veins in gneiss, whilst in Finland, Madagascar and in other parts of the United States, it is found in pegmatite veins.

The colour of the Gillingarra mineral in mass is dark grey-green, that of the coarse powder (30 mesh) between 41^3 and 41^3i (Ridgway). It is translucent in thicknesses up to 0·5 mm.

The specific gravity of the cleanest concentrate obtainable with methylene iodide was 4·34. As this was found to carry 1·28 per cent. of adherent and included quartz, the true specific gravity is 4·38.

The refractive index was determined for me by Mr. H. Bowley by immersion of some of the analysed powder in varying mixtures of piperine with iodides of arsenic and antimony, using a sodium light. All the granules had a greater N than a mixture with 30% of iodides (N, 1·773), and a lesser N than a mixture with 35% of iodides (N, 1·792). Immersed in a mixture with 32·5% of iodides (N, 1·782) some grains were found to have a slightly higher N than the medium, some a slightly lower. The values of N for the piperine-iodide mixtures quoted above are those of H. E. Merwin, quoted by E. S. Larson.* The figure obtained is somewhat lower than previously recorded values of N for gahnite, viz., 1·788, 1·790, 1·792, 1·815, 1·820. It is to be expected that the value of N will vary with different ratios of Zn to Fe and Mg.

For the analysis a concentrate from the mica schist was carefully separated with CH_2I_2, and covered for a few seconds with hydrofluoric acid, then washed and dried. Even after this treatment traces of quartz and muscovite remained, partly adherent to, and partly enclosed in, the gahnite granules.

The results obtained were :—

	A.		B.	
	per cent.	mols.	per cent.	mols.
Al_2O_3	56·96	559	57·70	566
Cr_2O_3	·09		·09	
ZnO	30·98	381	31·38	565
FeO	8·43	119	8·54	
MnO	·10		·10	
NiO	·01		·01	
MgO	2·35	58	2·38	
SiO_2	1·28	...	...	
	100·20		100·20	
G	4·34		4·38	
N	...		1·782 ± ·005	

A is the composition of the cleaned concentrate ; B the same, recalculated after rejecting the silica.

Wodgina.—During the mechanical concentration for tantalite of the surface soil on M.L.'s. 86 and 87, several crystals of gahnite have been observed. They are perfect octahedra, with angles typical of the isometric system, and isotropic under the microscope. They vary from 5 to 10 mm. in diameter, are translucent, and of a pale yellowish-green colour. Their uniformly high specific gravity, 4·49, leaves no doubt as to their identity. They have probably been shed from the famous tantalum-bearing pegmatite which traverses these leases.

Gahnite has previously been recorded in the State at Nevoria in a quartz vein, and at Greenbushes and Nannup in alluvial tin concentrates.

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* Micros. Det. of the non-opaque Minerals, 1921, p. 17.

(6.) HYPERSTHENE, WARRAMBU, MUR. DIV.

From Warrambu, in the Archæan complex between Mt. Magnet and Sandstone, some detrital specimens of hypersthene of unusual type have been received. They are flat masses about 10 cm. long and 2 thick, and over 4 cm. wide. The original width is unknown as the specimens had been fractured lengthwise before they were examined. Each specimen consists of a single crystal individual with two well-defined cleavages, one parallel to the flat face, the other, also a longitudinal one, practically at right angles to it. On a fresh surface the colour is approximately Ridgway 21^4k (dark greyish-olive), but on the exposed surfaces the mineral has weathered to a rusty brown.

Under the microscope the prismatic powder is transparent and colourless, and has a straight extinction and positive elongation, with strong birefringence. Measurements of refractive indices by Mr. H. P. Rowledge gave Ng 1·678, Nm 1·664, Np 1·654, all ± ·003. Small brownish stains indicative of incipient oxidation of the iron, penetrate deeply in parts, besides which there are numerous minute inclusions of granular magnetite, as well as of both a green and a colourless amphibole in small fibres and crystals. The total extraneous matter might amount to between 5 and 10 per cent. by weight.

An analysis gave the following figures :—

	Theory.	Warrambu Mineral.		
	$MgFeSi_2O_6$.	%	mols.	
SiO_2	51·82	48·56	808	
Al_2O_3	...	·37	4	53
Fe_2O_3	...	7·83	49	
FeO	30·87	27·24	379	708
MnO	...	·63	9	
MgO	17·31	12·39	307	
CaO	...	·75	13	
Na_2O	...	*nil*	...	
K_2O	...	·08	1	
H_2O+	...	2·19	121	
H_2O-	...	*nil*	...	
TiO_2	...	·18	2	
P_2O_5, CO_2	...	*nil*	...	
		100·22		
G.	...	3·45		
N.	...	1·678, 1·664, 1·654		

Analyst, H. P. Rowledge.

Allowing for the impurities detected by the microscope, and apart from the high water content, the composition might be that of hypersthene, as well as of cummingtonite or anthophyllite. Of these the last two usually contain several per cent. of water, but hypersthene, at any rate in the newer rocks, is usually anhydrous or almost so. Doelter however (H.B. der M.Ch. II., 336) quotes a hypersthene from the Nure Valley (Italy) with 2·78 per cent. H_2O, and one from Kraubat (Austria) with 3·03 per cent., besides several with more than one per cent.

A consideration of the density and optical sign still leaves the same doubt as to classification. The straight extinction in every position however, rules out cummingtonite, which is monoclinic with a maximum extinction of 10° to 20° with the axis of elongation.

A comparison with Winchell's graphs (Elements of Opt. Miner. II., 177 and 204) for the refractive indices of anthophyllite and hypersthene, is not very helpful in coming to a decision, as the following figures show :—

Mineral.	Hypersthene.	Warrambu Mineral.	Anthophyllite.
Per cent. of $FeSiO_3$ mols	40–70	55	40–70
Ng	1·731— ?	1·678	1·667—1·698
Nm	1·729— ?	1·664	1·658—1·690
Np	1·716— ?	1·654	1·650—1·680
Ng–Np	·015—·021	·024 ±	·016—·018

In considering these figures it is to be remembered that those given for hypersthene are for practically anhydrous minerals, and that they would be lower for corresponding compounds with 2 per cent. of water.

Coming finally to the prominent prismatic cleavage, the angle m¹ m⁴ in hypersthene is 88°, in anthophyllite 125°, and in Warrambu mineral approximately 90°. One appears therefore to be justified in classifying the last named as a hypersthene with an unusually high proportion of iron oxide and water.

(7.) MAITLANDITE AND NICOLAYITE (Spp. nov.), WODGINA, N.W. DIV.

Under the provisional classification of mackintoshite and thorogummite, the writer first drew attention to two silicates of thorium and uranium found at the north end of the main tantalum bearing pegmatite at Wodgina. This was in the Annual Report of the Geological Survey of W.A. for 1911. This preliminary description was elaborated in Geological Survey Bulletin 48, and in the Journal of the Natural History and Science Society of W.A., Vol. IV., both published in 1912. Since then several other references to the two minerals have appeared in print, the original names being retained up to the present owing to an early doubt as to there being any constant specific differences between them and the original mackintoshite and thorogummite of Texas, which they closely resemble in outward appearance.

Recent investigations of several specimens of each mineral, and a visit to the mine where they occur, have convinced the writer that they are reasonably constant in composition and that the differences between them and the Texas minerals are sufficiently great to be specific. It is proposed therefore, to call the Wodgina " mackintoshite " by the name of maitlandite, in honour of A. Gibb Maitland, Government Geologist of Western Australia from 1896 to 1926, and the first geologist to visit Wodgina and publish a scientific report on its geology and mineralogy.* The other Wodgina mineral, formerly known as "thorogummite," it is proposed to call nicolayite, in honour of the late Rev. C. G. Nicolay who in 1881 started the first permanent collection of minerals in the State, in his capacity of Registrar of Minerals at the newly constituted Geological Museum at Fremantle. His collection was shown at

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* G.S.W.A., Bull. 23 (1906).

the Colonial and Indian Exhibition in London in 1886, and later transferred to Perth, where it became the nucleus round which grew the present national collection in the W.A. Museum. In 1881 he wrote "The Handbook of Western Australia" (second edition, 1896) which contained many of the earliest references to the minerals which had been discovered in the State.

The following table gives a comparison of the Wodgina minerals with the Texas minerals.

—	Mackintoshite Texas.	Maitlandite Wodgina.		Transition Mineral, Wodgina.	Nicolayite, Wodgina.	Thorogummite, Texas.
		A.	B.			
UO_3	?	traces	traces	29·95	37·33	22·43
UO_2	22·40	35·40	35·60	5·69	*Nil*	*Nil*
ThO_2	45·30	25·86	24·72	24·28	24·46	41·44
SiO_2	13·90	14·62	16·19	n.d.	15·30	13·08
ZrO_2	·88	...	...	...	...	...
Ce_2O_3	...	·10	·10	·34	·12	6·69
Yt_2O_3	1·86	...	·25		·32	
Fe_2O_3	...	...	...	·32	...	·85
Al_2O_3	...	...	...	...	...	·96
PbO	3·74	6·04	7·90	n.d.	7·78	2·16
FeO	1·15	1·57	·20	n.d.	...	...
MnO	...	...	·07	...	*Nil*	...
CaO	·59	6·02	1·28	n.d.	1·62	·41
MgO	·10	...	·15	...	·16	...
K_2O	·42	...	...	...	...	...
Na_2O	·68	...	...	...	...	...
H_2O+	4·31	n.d.	12·04	10·65	8·37	7·88
H_2O-	·50	n.d.	·88	1·02	4·19	1·23
P_2O_5	·67	...	...	...	...	1·19
$(Ta, Nb)_2O_5$ ...	...	...	·67	...	·40	...
Total	96·50	...	100·05	...	100·05	98·32
G	5·44	4·31	4·45	?	4·13	?
N	1·77 ± ·01	?	?	?	1·617	?

The accepted formulae are :—

Mackintoshite—$3ThO_2 \cdot UO_2 \cdot 3SiO_2 \cdot 3HO_2$.

Maitlandite—$2(Pb,Ca)O \cdot 3ThO_2 \cdot 4UO_2 \cdot 8SiO_2 \cdot 23H_2O$.

Nicolayite—$2(Pb,Ca)O \cdot 3ThO_2 \cdot 4UO_3 \cdot 8SiO_2 \cdot 21H_2O$.

Thorogummite—$2ThO_2 \cdot UO_3 \cdot 3SiO_2 \cdot 6H_2O$.

Mackintoshite and maitlandite are both amorphous, vitreous, and black in colour. They both also consist principally of thorium, quadrivalent uranium, silica and water. They differ however, in that maitlandite contains quite appreciable amounts of calcium and lead, and much more water than mackintoshite, whilst the ratio of thorium to uranium is quite different.

The Wodgina "transition mineral" is a microscopic intergrowth of maitlandite and nicolayite. The analytical figures are of interest in showing the uniform ratio of U to Th, and consistently low figures for Ce and Y in various specimens of these minerals.

Thorogummite and nicolayite are both amorphous, vitreous, and yellow in colour, and consist principally of thorium, sexavalent uranium, silica and water. They are both also derived by weathering, and autoxidation, from the corresponding UO_2 minerals. They differ in that nicolayite contains molecularly important proportions of calcium and lead, whilst the water is higher in the Wodgina mineral. Cerium and yttrium are practically absent from the nicolayite, and quite appreciable in thorogummite, and finally the ratio of $ThO_2 : UO_3$ is quite different.

Neither of these minerals occur in any abundance at Wodgina, in fact only about 50 grammes of maitlandite, and 100 grammes of nicolayite have been collected altogether. By further weathering they pass into pilbarite and finally into hydrothorite.

(8.) OPAL, POONA, MUR. DIV.

An unusual type of opal has been found in a glassy quartz vein on M.L. 94 at Poona. It is bright green in colour (near Ridgway 39′k, dark cinnabar green), the colour being due to the presence of chromium silicate.

The masses reach 2 or 3 cm. in length, and about 1 cm. in thickness, and are distinctly platy in structure, the surfaces of the plates, and parallel partings, being slightly undulating. It is translucent in chips 0·5 mm. thick.

The composition of an apparently homogeneous mass was :—

	%	mols.
SiO_2	77·26	1,286
Al_2O_3	·69	7
Fe_2O_3	·37	2
Cr_2O_3	6·41	42
FeO	·14	2
CaO	·46	8
MgO	2·03	50
Na_2O	·06	1
K_2O	·12	1
H_2O+	6·29	349
H_2O-	5·93	329
TiO_2	trace	
P_2O_5	·04	
	99·80	
G	2·14	

Analyst, H. P. Rowledge.

Of the silica 60·24 per cent. was soluble in warm 5% NaOH solution, 17·02 per cent. insoluble.

When the powder is examined under the microscope some fragments are perfectly transparent, homogeneous and isotropic. Many others contain minute films, often parallel, of a highly birefringent mineral, possibly fuchsite. Other plates again have a more unusual structure, containing one or more isolated or contiguous hexagons outlined by several thin concentric dark lines, formed of minute inclusions, the outermost hexagon being 0·1 to 0·2 mm. in diameter. These hexagonal areas are parallel over restricted areas, and extinguish in opposite pairs of sectors when the plane of polarisation is parallel or perpendicular to the external boundary lines of the sectors. In plain light they are of the same colour and transparency as the rest of the plate (*see* Fig. 15.).

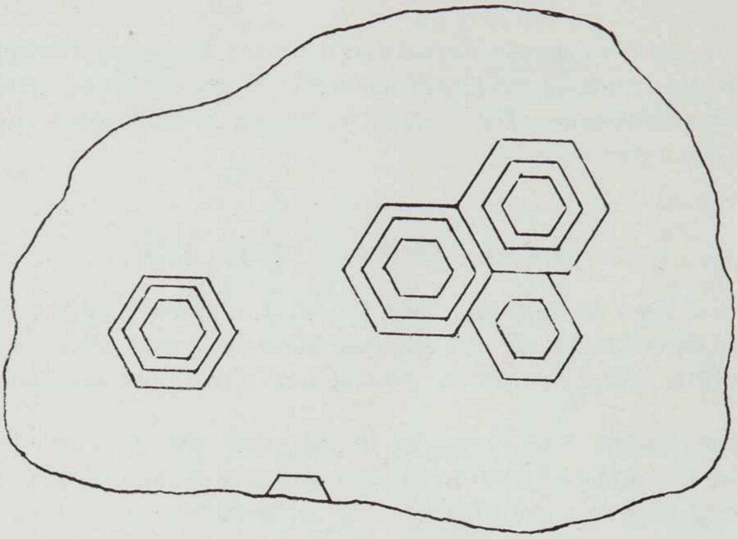

Fig. 15.—Chromiferous Opal, Poona.
x 75.

It would appear that the green platy masses consist largely of opal, pseudomorphous after some hexagonal, or pseudohexagonal, mineral containing chromium, such as stichtite or kammererite. Chromiferous beryl is common in felspathic and quartzose pegmatites at this place, but as beryl is highly resistant to chemical alteration, and is never known to possess an undulating parting, it is hardly possible that this is the parent mineral.

(9.) PSEUDOMALACHITE, COLLIER BAY, KIM. DIV.

Three very closely related basic phosphates of copper have been described in the literature. They are :—

	Cr.	G.	Ng.	Np.	Formula.
Tagilite (Hermann, 1846)	Mc.	4·1	1·85	1·69	$4CuO \cdot P_2O_5 \cdot 3H_2O$
Dihydrite (Hermann 1846)	Tc.	4·2	1·805	1·719	$5CuO \cdot P_2O_5 \cdot 2H_2O$
Pseudomalachite (Hausmann (1813)	Mc.	4·15	1·807	1·730	$6CuO \cdot P_2O_5 \cdot 3H_2O$ $5CuO \cdot P_2O_5 \cdot 2H_2O$ or $5CuO \cdot P_2O_5 \cdot 3H_2O$

Winchell (1927) describes them all as separate species. Dana (1896) treats each as a separate species, but is doubtful as to the formula of pseudomalachite, and hesitates as to whether it is distinct from dihydrite. Larsen (1921) says pseudomalachite and dihydrite are identical. All three are usually found in green fibrous masses in the outcrops of copper lodes.

In the Collier Bay District (West Kimberley) a few specimens of highly phosphatic copper ore have been found, in which the phosphorus is present as one or other of the above minerals. A bulk parcel of ore contained 9·46 per cent. of P_2O_5 and consisted of a mixture of quartz, pseudomalachite and chalcocite with a little limonite and malachite. A small fragment of the purest phosphate (which was distinguishable by its ready solution in dilute acid without effervescence) contained 22·34 per cent. of P_2O_5. It was impossible to collect more than a fraction of a gram of this material, but several grams of the purer phosphate were handpicked and analysed with the following results :—

		%
Insol. in cold dil. HCl	SiO_2 (quartz)	1·95
	Cu } Cu_2S	11·54
	S } Cu_2S	2·91
Sol. in cold dil. HCl	CuO	56·15
	Fe_2O_3	·47
	CaO	trace
	P_2O_5	18·47
	As_2O_5	*nil*
	CO_2	1·60
	H_2O+	7·28
	H_2O-	·07
		100·44
	Sp. gr.	4·18

After deducting quartz, chalcocite and limonite, the recalculated results are :—

	Per cent.	Total Mols.	Malachite.	Mols left.
CuO	67·27	845	88	757
P_2O_5	22·12	156	...	156
H_2O	8·69	483	44	439
CO_2	1·92	44	44	...
	100·00			
Sp. gr.	4·08			

After deduction of probable malachite, the molecular ratios of the phosphatic mineral are :—

CuO	5·01
P_2O_5	1·03
H_2O	2·90

This is very close to $5CuO \cdot P_2O_5 \cdot 3H_2O$, Dana's alternative formula for pseudomalachite, which may also be written $Cu_5(OH)_4 (PO_4)_2 \cdot H_2O$.

The Kimberley mineral is in dense masses of a "nickel green" colour (Ridgway 37″ k) with a small botryoidal surface. Where the mineral is less compact the green colour is much lighter, varying from the above to about "Montpellier green" (37″).

(10.) RIEBECKITE, HAMERSLEY RANGE, N.W. DIV.

The existence of " blue asbestos," *i.e.* fibrous riebeckite, in the range known at one end of its 300-mile length as the Hamersley, at the other as the Ophthalmia Range, has been rumoured for many years. The writer was shown specimens over 20 years ago, and in 1917 H. P. Woodward and A. Montgomery in a Mines Department Pamphlet* stated :

> " Blue asbestos of good quality and very strong fibre has been found in the North-West, and according to one prospector's report is in very large quantity. No official examination of the discovery has yet been made, however."

Again, in 1922, R. C. Wilson wrote† :

> " Specimens of crocidolite, said to have come from the Hamersley Ranges, have been exhibited in Perth, but no deposit has yet been officially examined."

Little credence has been given to these reports in the past, as no official inspection has ever been made of any of the reported deposits, which were in very inaccessible localities, and as it was known that occasional specimens of South African blue asbestos had been brought to the State many years ago, and later the same mineral had been imported in bulk for manufacturing purposes.

During this year, however, reports and specimens have been received at firsthand from trustworthy sources, and these show that typical blue asbestos of excellent commercial quality has been located at several points within a few miles of Mt. Margaret (Lat. 21° 58′, Long. 117° 50′) towards the western end of the range, and at one, if not more, points near Willi-Wolli Springs (Lat. 22° 53′, Long. 119° 15′) towards its eastern end. None of the deposits has been seen by any official of the Mines Department, but Mt. Margaret itself, and other parts of the range have been geologically examined in the past.‡ The whole of the range, from Mt. Margaret to Willi-Wolli consists of bedded rocks of the Nullagine series (late Precambrian ?), including sandstones, shales, limestones, jasperoids and lava flows, with occasional exposures of early Precambrian igneous rocks and schists in the deepest gorges and in the flanks of the range. In both areas the riebeckite appears to be associated with the jasperoids, which H. W. B. Talbot considers§ to be local variations of Nullagine shales or related rocks.

Mt. Margaret.—Specimens from this area show fibrous blue asbestos filling veins varying in width from 1 mm. to 4 cm. (0·04 to 1·5 inches). The enclosing rock is a banded siliceous ironstone, in which limonite is prominent, whilst narrow bands of granular magnetite are seen close to the asbestos veins. The veins are parallel to the bedding, whilst the asbestos fibres are at right angles, or almost so, to the walls. There is no break of the fibres in the centre of the veins as is so often seen in chrysotile veins.

In mass the colour of the mineral is indigo blue (Ridgway 47″ m) to Tyrian blue (47″ i) with very low translucency. As the mineral is disinteg-

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* The useful Minerals of W.A., p. 28. † A. R. Geol. Surv. W.A., 1921, p. 41.

‡ G.S. Bull. 33, pp. 119, etc. ; G.S. Bull. 83, pp. 100, etc. § G.S. Bull. 83.

rated, it pales through all tints to about pearl blue (49″ f). The masses are very easily teased out, yielding a very fine, soft, highly flexible and tough fibre. Individual fibres have a diameter of one micron or less, and small bundles have a negative elongation. Owing to the strong absorption parallel to the length it was impossible to obtain a close reading of the maximum extinction angle, but it appears to be 6° or slightly less for Na light. The pleochroism is always indigo blue parallel to the length, and lighter blue or yellowish-green at right angles thereto. The birefringence is low.

The compositions of typical unweathered specimens from 3 miles West of Mt. Margaret, and from 8 miles S.E. of Willi-Wolli Springs are given below, together with a recent analysis of a similar mineral from Kuruman, Bechuanaland.*

	Mt. Margaret.		Willi-Wolli.		Kuruman.
	%	Mols.	%	Mols.	%
SiO_2	51·86	863	51·94	864	50·50
Al_2O_3	·03	127	·24	121	...
Fe_2O_3	20·26		18·93		20·20
FeO	14·84	296	15·25	317	15·40
MnO	·01		·01		...
MgO	3·26		3·94		3·65
CaO	·49		·40		·80
Na_2O	6·12	102	6·00	99	4·40
K_2O	·28		·26		...
H_2O+	1·97	109	2·67	148	4·15
H_2O-	·68		·72		1·05
TiO_2	·03		·01		...
CO_2	·02		*nil*		...
P_2O_5	·05		*nil*		...
Cr_2O_3	*nil*		*nil*		...
	99·90		100·37		100·15
G	3·31		3·27		...
Analyst—	J. N. Grace.		J. N. Grace.		J. McCrae.

Excess silica and water over theoretical requirements appear frequently in analyses of asbestos of all kinds. This may be due to thin films of talc or opal on the surface of the fibres. The calculated excesses by weight in these two cases are SiO_2, 3·54 and 3·78 per cent; H_2O, 1·42 and 2·27 per cent. Deducting these, the analyses, in terms of known and assumed isomorphous molecules, prove to be:—

	Mt. Margaret. mols. per cent.	Willi-wolli. mols. per cent.
$NaFe'''(SiO_3)_2$	50·8	49·5
$Fe_2''(SiO_3)_2$	36·8	39·5
$HFe'''(SiO_3)_2$	12·4	11·0
	100·0	100·0

Some authors consider the Fe_2O_3 here calculated as $HFe''' Si_2O_6$ to be present as isomorphous Fe_2O_3, i.e. (Fe_4O_6), which does not appear probable to the present writer, and would leave a still larger excess of silica and water to be explained.

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* J. Ch. Met. Min. Soc. S. Af. 27, 287.

Willi-Wolli.—Specimens from a gorge eight miles S.E. of these springs are practically identical with those from Mt. Margaret, 100 miles distant. The enclosing rock is again a banded quartz-limonite jasperoid with strings of granules of magnetite, particularly against the ends of the asbestos fibres. The riebeckite is of the same indigo-blue colour, translucent only in fractions of a millimetre. The veins are somewhat wider, yielding fibre up to 5 cm. (2 inches) in length. It teases out readily to very fine, soft, highly flexible and tough fibres. Its composition has already been given.

Some of the specimens found as loose boulders in the valley have a thin crust of rusty decomposition products on them. These, however, do not penetrate far into the masses.

This is the first record of commercial crocidolite (fibrous riebeckite) in Australia.